

1 CLAIMS:

2 1. A system for providing cyclical impacts, said system
3 comprising

4 a housing with a longitudinal axis,
5 an impact member adjacent the housing,
6 a movable member movably disposed within the
7 housing, the movable member movable within the housing
8 transversely to the longitudinal axis of the housing, the
9 movable member positioned within the housing with a first
10 space on a first side thereof and a second space on a second
11 side thereof, gas in the first space and gas in the second
12 space, the first space substantially fluidly isolated from the
13 second space by the movable member, the movable member movable
14 to compress gas in one of the first space and the second space
15 while decompressing gas in the other of the first space or
16 second space so that a charge of compressed gas exits from the
17 housing to move the impact member,

18 the movable member movable continuously to provide
19 a series of a plurality of movements of the impact member, the
 system thereby providing a series of a plurality of impacts.

1 2. The system of claim 1 wherein the system is a system for
2 driving a pile into the earth and the housing is positionable
3 adjacent the pile so that the impact member impacts the pile.

1 3. The system of claim 1 wherein the system is a system for
2 drilling a borehole into the earth, the system including drill bit
3 apparatus, the housing positionable adjacent the drill bit
4 apparatus so that the impact member impacts the drill bit
5 apparatus.

6 4. A system for moving a drilling apparatus for drilling a
7 borehole in a formation, said system comprising
8 a housing with a longitudinal axis,

9 a movable member movably disposed within the
10 housing, the movable member movable within the housing
11 transversely to the longitudinal axis of the housing, the
12 movable member positioned within the housing with a first
13 space on a first side thereof and a second space on a second
14 side thereof, the first space substantially fluidly isolated
15 from the second space by the movable member, the movable
16 member movable to compress gas in one of the first space and
17 the second space while decompressing gas in the other of the
18 first space or second space so that a charge of compressed gas
19 exits from the housing to move an impact member for impacting
20 the drill apparatus for drilling the wellbore,

21 the movable member movable continuously to provide
22 a series of a plurality of movements of the impact member.

1 5. A percussion drill assembly for drilling a borehole in a
2 formation, said percussion drill assembly comprising

3 an elongated housing assembly having a first end
4 adapted to removably connect said drill assembly to a drill
5 string, and a second end adapted to receive a drill bit,

6 a first compartment formed within said housing
7 assembly and having a longitudinal axis,

8 a hammer piston positioned within said first
9 compartment for reciprocal motion within said first
10 compartment along the longitudinal axis of said first
11 compartment, said hammer piston dividing said first
12 compartment into a first chamber and a second chamber which
13 are substantially fluidly isolated from each other within said
14 first compartment by the presence of said hammer piston,

15 a fluid compressor positioned within said housing
16 assembly and having a first port in said first chamber and a
17 second port in said second chamber,

18 wherein a second compartment is formed within said

19 housing assembly, said second compartment having a
20 longitudinal axis; wherein said fluid compressor comprises a
21 compressor piston positioned within said second compartment
22 for reciprocal motion within said second compartment
23 transverse to the longitudinal axis of said second
24 compartment, said compressor piston dividing said second
25 compartment into a third chamber and a fourth chamber which
26 are substantially fluidly isolated from each other within said
27 second compartment by the presence of said compressor piston,

28 wherein said first port provides fluid communication
29 with said third chamber, and said second port provides fluid
30 communication with said fourth chamber,

31 a driver mounted in said housing assembly and
32 connected to said compressor piston so as to drive said
33 compressor piston to produce a high fluid pressure in said
34 first port and a low fluid pressure in said second port during
35 a first half cycle of operation of said fluid compressor and
36 to produce a low fluid pressure in said first port and a high
37 fluid pressure in said second port during a second half cycle
38 of operation of said fluid compressor, and

39 wherein said driver is connected to said compressor
40 piston to cause reciprocating movements of said compressor
41 piston within said second compartment.

1 6. The percussion drill assembly of claim 5 further
2 comprising

3 seals for sealing said fluid compressor from fluid
4 communication with any fluid received from the drill string,
5 whereby said compressor fluid system is a closed fluid system.

1 7. The percussion drill assembly of claim 5 wherein when
2 said drill assembly is being operated to impart an impact force to
3 a drill bit, a high fluid pressure in said first chamber and a low
4 fluid pressure in said second chamber causes a movement of said

5 hammer piston toward said second chamber, and

6 wherein when said drill assembly is being operated
7 to impart an impact force to a drill bit, a low fluid pressure
8 in said first chamber and a high fluid pressure in said second
9 chamber causes a movement of said hammer piston toward said
10 first chamber.

1 8. The percussion drill assembly of claim 5 wherein when
2 said housing assembly comprises a bit adapter at said second end of
3 said housing assembly for receiving a drill bit, said bit adapter
4 having an anvil surface exposed to said compartment, and

5 wherein said drill assembly further comprises a
6 drill bit removably connected to said bit adapter, and

7 whereby a predetermined extent of movement of said
8 hammer piston in one of its directions of movement causes said
9 hammer piston to strike said anvil surface and impart an
10 impact blow to said bit adapter when said drill bit is in
11 contact with a borehole bottom.

1 9. The percussion drill assembly of claim 8 wherein when
2 said driver comprises a fluid motor which is driven by a drilling
3 fluid passed downwardly through a drill string to the drill
4 assembly, and wherein the drilling fluid is exhausted from said
5 fluid motor through said second end of said housing assembly and
6 through said drill bit.

1 10. The percussion drill assembly of claim 5 wherein when
2 said driver comprises a fluid motor which is driven by a drilling
3 fluid passed downwardly through a drill string to the drill
4 assembly.

1 11. The percussion drill assembly of claim 10 wherein when
2 said fluid motor has a liquid inlet and a liquid outlet, said fluid
3 motor has a stator and a rotor positioned between said liquid inlet
4 and said liquid outlet, said driver comprises a rotary shaft and
5 said rotor is connected to said rotary shaft so that rotation of

6 said rotor causes corresponding rotation of said rotary shaft,
7 wherein the rotation of said rotary shaft drives said fluid
8 compressor, and wherein said liquid inlet of said motor is
9 connected to an inlet passageway in said first end of said housing
10 assembly so that liquid from a drill string flows through said
11 inlet passageway and then flows between said stator and said rotor
12 to said liquid outlet to effect rotation of said rotor with respect
13 to said housing assembly, thereby rotating said rotary shaft and
14 driving said fluid compressor.

1 12. A percussion drill assembly for drilling a borehole in a
2 formation, the percussion drill assembly comprising

3 an elongated housing assembly having a first end
4 adapted to removably connect said drill assembly to a drill
5 string, and a second end adapted to receive a drill bit,

6 a first compartment formed within said housing
7 assembly and having a longitudinal axis,

8 a hammer piston positioned within said first
9 compartment for reciprocal motion within said first
10 compartment along the longitudinal axis of said first
11 compartment, said hammer piston dividing said first
12 compartment into a first chamber and a second chamber which
13 are substantially fluidly isolated from each other within said
14 first compartment by the presence of said hammer piston,

15 a fluid compressor positioned within said housing
16 assembly and having a first port in said first chamber and a
17 second port in said second chamber,

18 wherein a second compartment is formed within said
19 housing assembly, said second compartment having a
20 longitudinal axis; wherein said compressor comprises a
21 compressor piston positioned within said second compartment
22 for reciprocal motion within said second compartment
23 transverse to the longitudinal axis of said second

24 compartment, said compressor piston dividing said second
25 compartment into a third chamber and a fourth chamber which
26 are substantially fluidly isolated from each other within said
27 second compartment by the presence of said compressor piston,

28 wherein said first port provides fluid communication
29 with said third chamber, and said second port provides fluid
30 communication with said fourth chamber,

31 a driver mounted in said housing assembly and
32 connected to said compressor piston so as to drive said
33 compressor piston to produce a high fluid pressure in said
34 first port and a low fluid pressure in said second port during
35 a first half cycle of operation of said first compressor and
36 to produce a low fluid pressure in said first port and a high
37 fluid pressure in said second port during a second half cycle
38 of operation of said first compressor,

39 wherein said driver is connected to said compressor
40 piston to cause reciprocating movements of said compressor
41 piston within said second compartment,

42 seals for sealing said fluid compressor from fluid
43 communication with any fluid received from the drill string,
44 whereby said compressor fluid system is a closed fluid system,

45 wherein said drill assembly is operable to impart an
46 impact force to a drill bit, a high fluid pressure in said
47 first chamber and a low fluid pressure in said second chamber
48 causing a movement of said hammer piston toward said second
49 chamber,

50 wherein said drill assembly is operable to impart an
51 impact force to a drill bit, a low fluid pressure in said
52 first chamber and a high fluid pressure in said second chamber
53 causes a movement of said hammer piston toward said first
54 chamber,

55 wherein said housing assembly comprises a bit

56 adapter at said second end of said housing assembly for
57 receiving a drill bit, said bit adapter having an anvil
58 surface exposed to said compartment,

59 wherein said drill assembly further comprises a
60 drill bit removably connected to said bit adapter,

61 whereby a predetermined extent of movement of said
62 hammer piston in one of its directions of movement causes said
63 hammer piston to strike said anvil surface and impart an
64 impact blow to said bit adapter when said drill bit is in
65 contact with a borehole bottom,

66 wherein said driver comprises a fluid motor which is
67 driven by a drilling fluid passed downwardly through a drill
68 string to the drill assembly, and wherein the drilling fluid
69 is exhausted from said fluid motor through said second end of
70 said housing assembly and through said drill bit,

71 wherein said fluid motor has a liquid inlet and a
72 liquid outlet, a stator and a rotor positioned between said
73 liquid inlet and said liquid outlet, said driver comprises a
74 rotary shaft and said rotor is connected to said rotary shaft
75 so that rotation of said rotor causes corresponding rotation
76 of said rotary shaft, wherein the rotation of said rotary
77 shaft drives said fluid compressor, and wherein said liquid
78 inlet of said motor is connected to an inlet passageway in
79 said first end of said housing assembly so that liquid from
80 the drill string flows through said inlet passageway and then
81 flows between said stator and said rotor to said liquid outlet
82 to effect rotation of said rotor with respect to said housing
83 assembly, thereby rotating said rotary shaft and driving said
84 fluid compressor.

1 13. A liquid-driven, gas-operated, percussion drill assembly
2 for drilling a borehole in a formation, said drill assembly
3 comprising

4 an elongated housing assembly, said housing assembly
5 having a first end and a second end opposite said first end,
6 and a longitudinal axis extending from said first end to said
7 second end,

8 an end portion of said housing assembly at said
9 first end being adapted for removably connecting said drill
10 assembly to a drill string, said end portion having a first
11 passageway extending therethrough for the passing of a liquid
12 received from the drill string,

13 an elongated first compartment formed within said
14 housing assembly, said first compartment having a longitudinal
15 axis which is at least generally parallel to the longitudinal
16 axis of said housing assembly,

17 a first piston positioned within said first
18 compartment for reciprocal motion within said first
19 compartment transverse to the longitudinal axis of said first
20 compartment, said first piston dividing said first compartment
21 into a first right chamber and a first left chamber which are
22 substantially fluidly isolated from each other within said
23 first compartment by the presence of said first piston,

24 a first shaft having a longitudinal axis, said first
25 shaft being rotatably mounted in said housing assembly with
26 the longitudinal axis of said first shaft being at least
27 generally parallel to the longitudinal axis of said housing
28 assembly, said first shaft being engaged with said first
29 piston such that rotation of said first shaft causes
30 reciprocating movement of said first piston within said first
31 compartment,

32 a motor positioned in said housing assembly and

33 having a liquid inlet and a liquid outlet, said motor having
34 a stator and a rotor positioned between said liquid inlet and
35 said liquid outlet, said rotor being connected to said first
36 shaft so that rotation of said rotor causes corresponding
37 rotation of said first shaft, said liquid inlet of said motor
38 being connected to the first passageway in said end portion of
39 said housing assembly so that liquid from said first
40 passageway flows between said stator and said rotor to said
41 liquid outlet to effect rotation of said rotor with respect to
42 said housing assembly, thereby rotating said first shaft and
43 reciprocating said first piston,

44 an elongated second compartment formed within said
45 housing assembly, said second compartment having a
46 longitudinal axis which is at least generally parallel to the
47 longitudinal axis of said housing assembly,

48 a second piston positioned within said second
49 compartment for reciprocal motion within said second
50 compartment along the longitudinal axis of said second
51 compartment, said second piston dividing said second
52 compartment into a first upper right chamber and a first lower
53 chamber which are substantially fluidly isolated from each
54 other within said second compartment by the presence of said
55 second piston,

56 a bit adapter having an anvil surface at a first end
57 thereof and a drill bit receiving opening at a second end
58 thereof, said bit adapter being removably attached to said
59 second end of said housing assembly with said anvil surface of
60 said bit adapter being exposed to said first lower left
61 chamber,

62 a second passageway providing fluid communication
63 between said first right chamber and a first one of said first
64 upper chamber and said first lower chamber,

65 a third passageway providing fluid communication
66 between said first left chamber and a second one of said first
67 upper chamber and said first lower chamber,

68 seals for sealing said first and second compartments
69 and said second and third passageways from fluid communication
70 with said first passageway, whereby said first and second
71 compartments and said second and third passageways constitute
72 a closed fluid system,

73 each of said first right chamber, said first upper
74 chamber, said first left chamber, said first lower chamber and
75 said second and third passageways having gas therein,

76 wherein movement of said first piston toward said
77 first right chamber compresses the gas in said first right
78 chamber and thus increases the pressure of the gas in said
79 first right chamber, in said second passageway, and in said
80 first one of said first upper chamber and said first lower
81 chamber, thereby causing the movement of said second piston
82 toward said second one of said first upper chamber and said
83 first lower chamber, and

84 wherein movement of said first piston toward said
85 first left chamber compresses the gas in said first left
86 chamber and thus increases the pressure of the gas in said
87 first left chamber, in said third passageway, and in said
88 second one of said first upper chamber and said first lower
89 chamber, thereby causing the movement of said second piston
90 toward said first upper chamber and said first lower chamber.

1 14. The liquid-driven, gas-operated, percussion drill
2 assembly of claim 13 further comprising

3 a drill bit removably connected to said bit adapter.

1 15. The liquid-driven, gas-operated, percussion drill
2 assembly of claim 13 further comprising

an eccentric element on said first shaft for acting on said first piston such that rotation of said first shaft in a single direction causes reciprocating movements of said first piston within said first compartment perpendicular to the longitudinal axis of said first compartment.

16. The liquid-driven, gas-operated, percussion drill assembly of claim 13 wherein said motor has a bypass passageway therein in communication with said first passageway for passing a portion of the liquid received from said drill string to said liquid outlet of said motor without said portion of the liquid going between said stator and said rotor.

17. The liquid-driven, gas-operated, percussion drill assembly of claim 13 wherein said rotor has a central longitudinal axis, said bypass passageway extends internally through said rotor, and said bypass passageway is not centrally located in said rotor.

18. The liquid-driven gas-operated, percussion drill assembly of claim 13 wherein said second end of said housing assembly comprises an annular chuck positioned outwardly of and coaxially with an intermediate portion of said bit adapter, whereby said bit adapter can slide axially with respect to said chuck so that said bit adapter can move downwardly with respect to said chuck when the drill bit is not in contact with a borehole bottom.

19. A method of operating a percussion drill assembly for drilling a borehole in a formation, said method comprising

charging a closed fluid system of a percussion drill assembly with a fluid under pressure, said percussion drill assembly comprising an elongated housing assembly having a first end adapted to removably connect said drill assembly to a drill string, and a second end adapted to receive a drill bit, a first compartment formed within said housing assembly and having a longitudinal axis, a hammer piston positioned within said first compartment for reciprocal motion within

11 said first compartment along the longitudinal axis of said
12 first compartment, said hammer piston dividing said first
13 compartment into a first chamber and a second chamber which
14 are substantially fluidly isolated from each other within said
15 first compartment by the presence of said hammer piston, a
16 fluid compressor positioned within said housing assembly and
17 having a first port in said first chamber and a second port in
18 said second chamber, wherein a second compartment is formed
19 within said housing assembly, said second compartment having
20 a longitudinal axis; wherein said compressor comprises a
21 compressor piston positioned within said second compartment
22 for reciprocal motion within said second compartment
23 perpendicular to the longitudinal axis of said second
24 compartment, said compressor piston dividing said second
25 compartment into a third chamber and a fourth chamber which
26 are substantially fluidly isolated from each other within said
27 second compartment by the presence of said compressor piston,
28 wherein said first port provides fluid communication with said
29 third chamber, and said second port provides fluid
30 communication with said fourth chamber, a driver mounted in
31 said housing assembly and connected to said compressor piston
32 so as to drive said compressor piston to produce a high fluid
33 pressure in said first port and a low fluid pressure in said
34 second port during a first half cycle of operation of said
35 first compressor and to produce a low fluid pressure in said
36 first port and a high fluid pressure in said second port
37 during a second half cycle of operation of said first
38 compressor, and wherein said driver is connected to said
39 compressor piston to cause reciprocating movements of said
40 compressor piston within said second compartment,
41 connecting said first end of said drill assembly to
42 a drill string,

connecting said second end of said drill assembly to a drill bit,

operating said drill assembly to impart an impact force to said drill bit by actuating said motor to rotate said shaft and thereby reciprocate said compressor piston, thereby causing the movement of said hammer piston whereby movement of said hammer piston imparts an impact force to said drill bit.

20. The method of claim 19 further comprising

rotating the drill string to thereby rotate said drill bit.

21. The method of claim 19 further comprising

passing drilling fluid through the drill string into and through said motor to actuate said motor and passing drilling fluid from to and through said drill bit to flush drilling debris from the drill bit.

22. The method of claim 19 wherein the fluid which is charged to said closed fluid system is a gas.

23. A method for providing cyclical impacts, the method comprising

impacting an item with an impact member of a system, the system for providing cyclical impacts, the system comprising a housing with a longitudinal axis, the impact member adjacent the housing, a movable member movably disposed within the housing, the movable member movable within the housing transversely to the longitudinal axis of the housing, the movable member positioned within the housing with a first space on a first side thereof and a second space on a second side thereof, gas in the first space and gas in the second space, the first space substantially fluidly isolated from the second space by the movable member, the movable member movable to compress gas in one of the first space and the second space while decompressing gas in the other of the first space or

16 second space so that a charge of compressed gas exits from the
17 housing to move the impact member, the movable member movable
18 continuously to provide a series of a plurality of movements
19 of the impact member, the system thereby providing a cyclical
20 series of a plurality of impacts.

1 24. A method of drilling a wellbore in an earth formation
2 with a drilling apparatus, the method comprising

3 impacting a drilling apparatus with an impact member
4 of a system, the system for moving the impact member, the
5 system comprising a housing with a longitudinal axis, a
6 movable member movably disposed within the housing, the
7 movable member movable within the housing transversely to the
8 longitudinal axis of the housing, the movable member
9 positioned within the housing with a first space on a first
10 side thereof and a second space on a second side thereof, the
11 first space substantially fluidly isolated from the second
12 space by the movable member, the movable member movable to
13 compress gas in one of the first space and the second space
14 while decompressing gas in the other of the first space or
15 second space so that a charge of compressed gas which exits
16 from the housing to move an impact member for impacting the
17 drill apparatus for drilling the wellbore, the movable member
18 movable continuously to provide a series of a plurality of
19 movements of the impact member to provide a plurality of
20 impacts to the drilling apparatus.